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ABSTRACT

This paper describes the Project for Integrating the University, the School, and Society (PIUES), developed as part of an effort to restructure the teaching of engineering at the Pontifical Catholic University in Rio de Janeiro, Brazil. New courses for high school teachers were developed that focused on the debates over basic concepts in chemistry, current themes associated with chemistry, alternative ways of teaching, and training in lab practice. Teachers indicated enthusiasm for the redesigned courses. (Contains 14 references.) (WRM)

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A Program of Integration for the University and the High School in the Field of Chemistry

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Abstract

Within the scope of a project meant to reestructure the teaching of engineering (REENGE) at the Pontifical Catholic University - Rio de Janeiro,it was created the Project for Integrating the University, the School and the Society (PIUES). This project was initiated with the purpose of catalyzing, within the limits of their actions, the changes seen as needed in the teaching of Sciences in High Schools. Concerning the Department of Chemistry, the actions of the PIUES included distinct activities towards the students and the teachers. About the activities towards the students, it is worth mentioning the offer of lectures at their High Schools on themes of current interest involving the knowledge of Chemistry (pollution, new materials etc), receiving those students in the graduation laboratories of the University to perform practical classes and/or to visits to the research laboratories of the Department.

The activities towards the teacher consisted of 4 updating courses for High School Chemistry teachers, in a total of 130 teachers from High Schools of the Rio de Janeiro state. Four points were focused: (i) the debate of basics concepts in chemistry; (ii) the debate of current themes associated with chemistry; (iii) the debate on the alternative ways of teaching, including the debate on didactic resources; (iv)training in lab practice.

The quality and the aptness of the courses were evaluated by the participants themselves who answered specific questionnaires. It was noticed that the course was very well accepted by the participants and it became clear that the teachers have an enormous eagerness to improve their performance which they recognize as deficient in some points.

It is still difficult to evaluate any effective change in the attitude of the teachers who attended the course after they returned to their schools because the project provided no fund for this kind of supervision. A survey based on spontaneous answers and self-evaluation is in progress.

Introduction

The increasing difficulty in mastering the basic concepts in science experienced by the students entering the Brazilian Universities has become each year more evident. The phenomenon is reflected in the alarming rate of failures and in the high level of evasion during the two initial semesters of the basics engineering courses.

One of the causes of this process is surely the mere quantitative expansion of the basic schooling during the 70's and the 80's. The question of quality in the teaching was relegated to a second position and, in that same period, the vertiginous fall of the teacher's salaries in that segment turned the profession less attractive and less competitive.

Inside the university, a series of measures was taken in order to compensate for such deficiencies, as follows: introduction of supportive disciplines in the curriculum, assistance through monitors, reduction of the number of hours spent with lessons during the first semester, reformulation of the courses etc. All this, having in mind to avoid the high rates of evasion while maintaining the level of excellence desired for the course. It became clear that the learning difficulties detected were due not only to the lack of specific knowledge but even more to the absence of a more critical and aware thought from the students with reference to learning. Such difficulty had its origin (together with other factors) in the way that Sciences was taught in high schools. Which way was that? It is hard to define it in a few words but roughly it might be called a non critical way of teaching, more inclined to coach the student so that he succeeds his tests to enter the university (if he does) than to make him understand the process of elaboration of science. This way of teaching may also be called alienated since it does not encourage (actually it is liable to prevent) an effective participation of the students in the learning process and it turns the students into mere receptors of the knowledge previously defined and organized by the teacher. This becomes evident in the almost total absence of regular practical lessons in the high schools of Rio de Janeiro State, either public or private.

As habit adapts to a reality and the repetition of habit forms culture, a culture was established here, formed of expositive lessons, absence of laboratory, books with few texts and questionable analogies, "learning" through coaching etc. In the waters of this sea the majority of teachers immersed, even because that was the best way to adapt to the working conditions offered, such as: low salaries and the consequent excess of work, class with large numbers of students, schools without laboratories, little or no incentive to a critical teaching and the idea that coaching may replace

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learning. It might actually be called a fiction teaching, by which the program of the discipline is accomplished without a real evaluation of what was learned. However, in terms of current (and desired) "normality" everything seems to function.

Immersed in this sea for 20 years, a fair portion or the most part of the Science teachers had no idea that another kind of performance might be possible. In this context, any attempt to impose alternative methods would be doomed to failure.

Having this view in mind, in PUC-Rio, within the scope of a project meant to reestructure the teaching of engineering (REENGE),it was created the Project for Integrating the University, the School and the Society (PIUES). This project was initiated by the Department of Physics and followed afterwards by the Department of Chemistry with the purpose of catalyzing, within the limits of their actions, the changes seen as needed in the teaching of Sciences in high schools.

Description of the Activities

Concerning the Department of Chemistry, the actions of the PIUES included distinct activities towards the students or towards the teachers. About the activities towards the students, it is worth mentioning the offer of lectures at their High schools on themes of current interest involving the knowledge of Chemistry (Pollution, New Materials etc), receiving those students in the graduation laboratories of the University to perform practical classes and/or to visits to the research laboratories of the Department.

The activities towards the teacher consisted of 4 updating courses for High School Chemistry teachers, in a total of 130 teachers from High Schools of Rio de Janeiro state. Those courses were sponsored by the Ministry of Education, after application and approval of the specific projects. Thanks to this support, each teacher in the course received a scholarship of about U$ 250.00 in addition to didactic material consisting of published lecture notes which included texts, papers, procedures etc. Table 1 show the lectures, texts, laboratories experiments and "minidemos" proposed to the attendants.

Table 1. High school teachers updating courses : activities, lectures, minidemos and texts

• Texts
1. Atomic theory as a model of science evolution[1].
2.Chemical reactions: stoichiometry[2].
3. Environmental Chemistry in action: a new approach to Chemistry teaching[3].
4. Didactic books: barriers to Chemistry learning[4].
5. Phenomena conception in Brazilian Chemistry teaching : beyond didactic books[5].
6.Interactions and transformations in Chemistry teaching[6].
7. Historic evolution of the Avogadro's constant[7].
8. Use of alternative materials in experimental Chemistry teaching[8].
9. Alchemy and Chemistry[9].
• Lab experiments
1. Avogadro's hypothesis[2].
2. Chemical reactions : the mole concept[2].
3. Electrochemistry[11].
4. Water quality and purification[12].
5. Reaction of Mg and HCl : a quantitative approach[10].
6. Electrolytic titration[13].
7. Carboxylic acids and its derivatives: everyday utilization[14].
8. Heat of reaction[10].
9. Reaction rates[10].
10. Chemical equilibrium[10].
11. Electrochemical cells[10].
• Lectures
12. Atomic theory as model of Science evolution.
13. Electrochemistry
14. Proportions in chemical reactions.
15. Real themes in Chemistry: New Materials.
16. Tendencies in the current Chemistry didactic books for the high school level.
17. History of Chemistry as a didactic tool for teaching Chemistry.
18. Organic Chemistry in the high school.
19. Real themes in Chemistry: Environmental Chemistry.
20. An experience of introduction of a new didactic Chemistry book.
• Short demonstrations (Minidemos)
21. Flame test.
22. Heterogeneous catalysis.
23. Natural pH's indicators.
24. A "samba school".
25. The first principle of thermodynamic.
26. Charles' Law
27. Common ion effect.
28. Hot dog Cell.
29. Permanganate reduction: chemical kinetics.
30. Avogadro's number measurement.

Activities, Detail and Discussion

Actions towards the high school students : Sporadic lectures or visits to the laboratories do not intend to have intense reflex on such a complex question as the one discussed in the introduction of this work. However remarkable facts should be mentioned: The majority of the High schools which accepted to receive the lectures or to visit the laboratories were those whose teachers had attended to the updating course. Although 35

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invitation letters were sent to High schools offering the free services of the program, only 12 schools answered. PUC-Rio is situated in the area of Rio de Janeiro city's highest income. Inside this area there is a large number of High schools, from where the majority of the students of PUC-Rio come. However, only a small fraction of those schools joined to the Program. Thus most of the schools benefited by the Program were out of this area. Most of their those students belong to the medium class and to the lower medium class. These students, owing to their low acquisitive power, cannot afford to study in PUC-Rio, a private University, in which the annual cost of a engineering course amounts to U$ 10,000.00. The causes of this phenomenon can only be speculated. In the authors' belief the High schools staff whose students belong to the higher medium class, thinks is that "there is nothing wrong with our teaching" since they have, in general, a good result in the test to enter the University. There is nothing further from reality than this. As those tests are eminently classifying tests, it means that the students from the mentioned High schools have only a better preparation for the tests than the other students. Actually this better preparation is not necessarily connected to a better teaching but to various causes, including those associated with the better chances offered by the social class they belong to.

It doesn't invalidate the program the fact that the benefited schools were not those from which the students of PUC-Rio come, since the program aims at the improvement of the science teaching in the High schools in general.

Regarding the 688 participating students, they answered to opinionated questionnaires at the end their activities. The favorable answers and the touching interest they showed during the activities gave evidence of their eagerness for alternatives to the "normal" teaching. This also contradicts the idea that students are "a priori" not interested in learning sciences, showing that the difficulty in communication is much more due to the inadequate teaching methods employed.

Action toward the teachers : For sure one of the reasons why the method employed for teaching sciences in High schools is mainly discursive and authoritarian, instead of a process of (re)discovering their fundamental principles, also lies in the fact that the teacher himself has not experienced this process. Usually, in Brazil, the licentiate degree courses are reduced bachelorships which the superposition of the so-called pedagogic disciplines. Owing to the low salary prospects of the profession, migrating to the licentiate degree courses is the option for those who don't feel at ease applying for vacancies in the courses for which the competition is stronger. Moreover, second line universities (where there is no research and the majority of the teachers are paid by hour) are those receiving /attracting the segments excluded from the first line universities, to whom licentiate degree courses are then an option. In short, the teachers thus formed will not have experience in the process of producing knowledge and they will repeat with their future students the authoritarian teaching they received.

In those licentiate degree courses it is also poor the discussion of history of science, which is our opinion a fundamental discipline to the understanding of the process of constructing knowledge in science.

For all this, it is essential to act on the active teacher so that any attempt to change the present situation may be succeeded. And it should not be forgotten that such changes pass along a strong motivation from the teacher owing the already discussed enormity of the forces exerted to maintain the status quo. In this way the major part of this Project's energy was channeled towards the updating courses for the teachers.

Therefore three courses were held, each of 80 hours (a fourth course of 120 hours is in progress) with a total of 130 attendant teachers.

The courses were focused on four points: (i) the debate of basics concepts in chemistry; (ii) the debate of current themes associated with chemistry; (iii) the debate on the alternative ways of teaching, including the debate on didactic resources; (iv)training in lab practice.

The best was done during the course to avoid repeating the mistakes sought to neutralize. Thus emphasis was given to increase the direct participation of the students. The expositive lessons lasted up to a maximum of two hours a day, in the morning. The rest of the morning was spent in reading and debating the texts, free access to information in the field of teaching chemistry (Infoteca), videofilms, short demonstrations ("minidemos") etc. All afternoons were spent inside the labs, where the participants carried out practical works.

The chosen basic chemistry topics for debate were "atomic theory", "stoichometry" and "electrochemistry". In the case of atomic theory, the option was for an historic point view, emphasizing the interrelation between experimental facts and the evolution of the atomic models. Special attention was given to the Dalton model, from where a bridge was built from the macroscopic to the microscopic world. In the case of the stoichometry an option for an eminently experimental focus was made : The determination of the saturation point of the reaction $Pb^{2+}_{(aq)} + 2I_{(aq)} \rightarrow PbI_{2(s)}$ was used to access the stoichometry principles, so that from the experimental data the Proust law and the balance of the chemical equation could be inferred. Worthy of note is that the precipitate mass was not weighed in a balance (it would imply in drying the precipitate which would take a long time) but it was determined by the measurement of the precipitate height formed inside the test tubes. Concerning electrochemistry, the focus was also experimental. A table of relative potentials was build (the semi-cell Cu/Cu^{2+} was used as reference) by reading the potentials of various cells, and used to foresee the potentials of new cells and check the foresight in practice.

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Concerning the current themes, Environmental Chemistry and New Materials were chosen. In both cases, the points emphasized had a close connection with the usual high school Chemistry programs, showing how those themes may enrich, illustrate and make classes more attractive.

Half the time of the seminars in the courses was used to debate the alternative ways of teaching, including the criticism on the traditional focus : criticism on the most popular didactic books on Chemistry published throughout the country, whose majority reflects the already mentioned questionable mentality formed during the 70's and the 80's. On the other hand, alternative materials were presented. Some of are already, in use in few isolated teaching experiments despite the attention they deserve. It was also presented low cost materials to be used in practical lessons (a practical lesson for 99 cents!); the History of Chemistry as a didactic instrument as well as and the exhibition of "minidemos", fast (less than 10 minutes long), inexpensive, attractive demonstrations that may be used to introduce or illustrate chemical concepts. The "minidemos" were picked up or adapted from various sources. One afternoon was dedicated to the "Infoteca", meaning that the sources of information connected to the teaching of Chemistry gathered by the group were presented to the students, including Internet sites.

Finally, the group carried out 8 to 9 practical in a total of around 30 hours. The long time spent inside the lab not only supported the authors view about the nature of Chemistry as an eminently experimental science but it was also due to the fact that the lab experience of the majority of the high school Chemistry teachers was obtained during their university years. From the day they start in their professional life on, there will be only place for cursive lessons, one following the other, since only an insignificant fraction of the high schools offer regular practical lessons. Practical lessons imply additional costs which neither private nor public schools seem to be willing to take on. Many schools do not even have a lab. Labs demand maintenance and technicians. Practical lessons demand preparation and the teacher must stay for a larger remunerated time in the school. The final result is that there is no chance of carrying out practical lessons. And if there would be any chance, it would imply an immense extra charge to the teacher who is already overcharged and he thus end by avoiding the task. After years of cursive lessons, the teacher has improved them (i.e. they are perfectly adapted to the various situations he faces) and he doesn't want to change himself. His outlying position implies in loss of skilling, increasing his lack of confidence concerning the introduction of practical lessons, even when surprisingly favorable conditions appear. That is why an intense activity in the laboratory was considered necessary. It must be clear that the practical lessons were directed to the teacher with the intention of increasing his skilling in the laboratory and to show him how to explore to a maximum those lessons aiming at learning the chemical concepts.

Conclusions

After going through this experience only for 2 years, it would be premature and perhaps even pretentious to seek to measure any kind of improvement in the teaching of Chemistry in the high schools of Rio de Janeiro. It became even difficult to evaluate any effective change in the attitude of the teachers who attended the course after they returned to their schools because the project provided no fund for this kind of supervision. Questionnaires were sent through the mail and a survey based on spontaneous answers and self-evaluation is in progress. So, the changes to be discussed here are those which seemed to be achieved, based on the answers to the questionnaires handed at the beginning and at the end of the courses, and on the final evaluation of the course.

The quality and the aptness of the courses were evaluated by the participants themselves who answered the questionnaire shown in table 2, where grades from zero to ten were given to each item. The respondents, of course, had no need of identifying themselves. It was noticed that the course was very well accepted by the participants and that there was a considerable improvement in the various items from the first or the third course. The answers were homogeneous, showing coefficients of variation always lower than 20%. The considerable improvement of item 6, from the 1st to the other courses, is certainly due to a better understanding of the purpose of the practical lessons, meant to provide skilling to the teachers and not necessarily to be applied in their schools of origin. Many respondents from the 1st course referred to the lessons as not much adequate because they were thinking of adapting them to the conditions offered by their schools of origin.

Various of the course's seminars were introduced by invited teachers, outside the team, with great experience on the topic. The evaluation of each teacher's performance led to expressive improvement shown in item 5 (quality of the lectures) from the first to the third course.

In the second and third courses a second questionnaire (table 3) searched to evaluate the reflex of the course in the participant himself. The answers' profile of the 2nd and the 3rd course is quite similar. The majority agreed that the courses contributed to enrich their personal experience and to incite changes. About the applicability of those changes, however, the teachers became a whole lot more skeptics : from item a to b in the questions 1, 2 and 4 the grades fell systematically. This may show that the work conditions are really very much unfavorable to those changes, or that the teachers perceive them as so, or merely that they are not motivated enough to achieve them. However, concerning the "minidemos" there are far more favorable

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expectations, certainly because they deal with simple demonstrations which demand little additional work from the teacher, besides being really illustrative. Another interesting aspect, made clear in the answers to items 6 and 7, is the strong desire to follow the studies and an evident joy for having had the chance of returning to study and making progress.

It was also asked from the participants a free evaluation of the course, up to the maximum of 1 page. Based on the answers, we can confirm that the courses incited changes in attitude and in strategy in the classroom besides enriching the participants' specific knowledge thus contributing, so we hope, to the improvement of the teacher's performance in the classroom. Among the positive points of the courses, stress was placed on the short demonstrations (minidemos), the interchange of experiences between the participants and the university, the good quality of the lectures, the opportunity to make use of a good laboratory in the university, the use of laboratory alternative materials, the reformulation of concepts, the access to Internet and the harmonious relations with the coordinating team. About the aspects that might still be improved, it was requested an increase in the time spent in the exploration of the sites of interest in Internet and the adaptation of the practices to the conditions of their schools of origin, although the purpose of such practices, the coordinating team made it clear, was not to repeat them in their schools of origin. The participants became extremely enthusiastic and they have even suggested the continuity of the updating courses.

It became clear that the teachers have an enormous eagerness to improve their performance which they recognize as deficient in some points. This aspect is seen as in the same level of relevance as the question of salaries. Many concepts in Chemistry are not clear but in their everyday haste they find no means to supply such deficiencies, hence the joy with which the courses were received. There was also strong criticism from the groups concerning the majority of their colleagues whom they perceived as conformists and whose lack of incentive would be a great obstacle in the way to the changes. It is worthy to remark here that they didn't perceive themselves as conformists although they were somewhat skepicals about the possibility of applying the knowledge obtained to the reality of their classrooms. Usually, in this case, there was reference to outside factors which would prevent such changes, even after extremely simple and inexpensive materials were introduced. The only exception was for "minidemos". The new courses intend to deal with this question.

From the interaction with the participants it became clear to the coordinating team the need of implementing a pilot – project in order to put into practice in the real context of teaching, inside the classroom, the proposals put forward by the team.

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Table 2. Course evaluation : questionnaire and results.

	Course 1 (n = 30)	Course 2 (n = 20)	Course 3 (n = 30)
	X± (S)	X± (S)	X± (S)
Course organization	8.7 (1.2)	9.0 (0.6)	9.0 (0.7)
Text adjustment	8.6 (1.3)	8.6 (1.0)	8.9 (1.1)
Didactic material quality	8.8 (1.3)	8.8 (0.8)	8.8 (1.1)
Lectures adjustment	8.1 (1.1)	8.1 (1.0)	9.2 (0.7)
Lectures quality	8.2 (1.3)	8.3 (1.0)	9.6 (0.4)
Experimental classes adjustment	7.9 (1.6)	8.9 (1.1)	8.5 (1.0)
Lab adjustment	8.4 (2.2)	9.3 (0.7)	9.1 (0.9)
Course extension	7.9 (1.8)	8.9 (1.2)	9.0 (0.9)
Adjustment practice-report	8.1 (1.7)	8.5 (1.2)	8.6 (1.0)
Equilibrium between practices and theoretical activities	8.7 (1.7)	8.7 (1.1)	8.8 (0.9)

X : average result ; s : standard deviation ; n : number of attendants / respondents

Table 3. Teachers' self evaluation : questionnaire and results

	Course 2 (n = 20)	Course 3 (n = 30)
1. Pedagogic knowledgment acquired in lectures		
a) enrich your personal formation	9.0	9.6
b) applicable in class	7.8	7.1
c) stimulate changes in your performance	7.4	9.1
2. Specifics knowledge acquired in lectures.		
a) enrich your personal formation	9.0	9.2
b) applicable in class	7.8	7.4
c) stimulate changes in your performance	8.2	8.8
3. Short demonstrations		

(Minidemos)		
a) enrich your personal formation	8.6	9.2
b) applicable in class	9.8	8.9
4. Alternative material in experimental classes.		
a) enrich your personal formation	8.6	8.9
b) applicable in class	8.4	8.7
5. Experimental classes will contribute to improve their performance		
a) in class	9.4	8.5
b)in laboratory	9.2	8.4
6. Course stimulate to follow their studies		
a) in chemical education	9.4	9.2
b) in other knowledge areas	9.0	9.4
7. Would you advise colleagues to participate of courses like this?	10.0	10.0

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